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Does the presence of international students improve domestic graduations in the US?☆

Melaku Abegaz[a,*], Sajal Lahiri[b], A.K.M. Mahbub Morshed[b]

[a] Department of Economics, Unversity of Minnesota Duluth, Duluth, MN 55812, United States
[b] Department of Economics, Southern Illinois Unversity Carbondale, Carbondale, IL 62901, United States

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ABSTRACT

We examine the impacts of international students on the graduation performance of universities in the states of Illinois and California, U.S.A. Using data on enrollment and graduation – disaggregated by universities, programs, and types of students – we follow two methods: a two-stage method and a one-step method. In the first stage of the two-stage method, we estimate university 'premiums' on graduations, and in the second stage, we examine how these premiums are affected by the graduation rates of international students. In the one-step method, we examine how international students affect the graduation of native students and of all students, separately for master's and PhD degrees, after controlling for enrollments and a number of program-specific and university-specific characteristics. In both methods, we allow for possible two-way causality. Our estimates suggest that international students generate positive externalities on the university graduation premiums among both native students and all students.

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1. Introduction

The US has been hosting a larger number of international students than any other country in the world. Enrollment of foreign students in US universities increased rapidly from over 310,000 in 1980 to over a million in 2016 (IIE, 2017); the latter figure represents 5.3% of the total number of students enrolled in US higher education in 2016. The presence of foreign students is much larger in graduate schools, particularly in the Science and Engineering (S&E) fields of study. They account for 16.7% of the total graduate school enrollments, and 49% of engineering and 48% of mathematics and statistics graduate students (Allum, 2014).

The social and economic impacts of immigration have generated vigorous policy debate among politicians, business owners, and academicians in the US as well as in other developed countries. Many studies have analyzed the effects of skilled immigrants including international students, on labor market outcomes, research production, and patenting in universities and business organizations (Borjas, 2006; Chellaraj, Maskus, & Mattoo, 2008; Peri, Shih, & Sparber, 2014; Stuen, Maskus, & Mobarak, 2012). A few studies have examined the impacts of international students on the graduate enrollment of native students. Borjas (2004), using the Integrated Postsecondary Education Data System (IPEDS), finds that an increase in the enrollment of foreign students crowd out native white men from graduate schools, while positively associated with the enrollments of native Asian, Black, and Latino students. In contrast, a study by Regets (2007) estimates a positive effect on the enrollments of US white and underrepresented students, but a negative effect on Asian-American students. More recently, Shih (2017) finds that international students do not crowd out, but actually increase domestic enrollment by cross-subsidizing the cost of enrolling additional domestic students. He argues that efforts to limit nonresident enrollment based on fears of domestic displacement may be misguided.

The literature on immigrant peer effects focuses on elementary and high school achievements of native students. Hunt (2012)

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* Corresponding author at: Department of Economics, University of Minnesota Duluth, 1318 Kirby Dr., Duluth, MN 55812, United States.
E-mail addresses: mtabegaz@d.umn.edu (M. Abegaz), lahiri@siu.edu (S. Lahiri), mmorshed@siu.edu (A.K.M.M. Morshed).

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Table 1
Mean share of foreign degree recipients (%).

Fields	Year	Illinois Uni.		California Uni.	National	
		PhD	Master's	Master's	PhD	Master's
Engineering (CIP = 14)	2009	61.9	68.2	40.5	57.5	38.1
	2005	72.0	62.3	40.1	60.4	41.9
	2001	63.2	50.8	34.5	53.5	39
Mathematics (CIP = 27)	2009	50.4	39.1	19.2	47.1	28.2
	2005	56.3	35.3	23.6	51.2	30.3
	2001	59.5	31.8	20.8	44.3	25.9
Social Sciences (CIP = 45)	2009	59.1	19.3	15.2	35.7	15.3
	2005	43.4	24.8	14.8	30.7	18.1
	2001	33.3	17.9	13.7	20.2	13.7
All fields	2009	56.3	44.2	28.2	47.8	30.1
	2005	54.7	40.7	28.9	49.8	32.3
	2001	48.9	34.3	27.9	40.6	30.5

Source: Author's calculation from IPEDS.

Table 2
First stage regressions for Illinois, selected years.

Dependent Var.: Degree granted	Master's			PhD					
	Total			Total			Native		
	2010	2007	2004	2010	2007	2004	2010	2007	2004
New Enroll.									
L1.	0.31***	0.26***	0.08**						
	(0.04)	(0.07)	(0.03)						
L2.	0.40***	0.53***	0.59***						
	(0.05)	(0.06)	(0.06)						
L3.	0.30***	0.19***	0.34***	0.35**	0.39***	0.37***	0.45**	0.44***	0.37***
	(0.05)	(0.06)	(0.05)	(0.15)	(0.04)	(0.07)	(0.19)	(0.09)	(0.07)
L4.				0.48***	0.18***	0.12***	0.27	0.26***	0.30***
				(0.15)	(0.05)	(0.04)	(0.18)	(0.06)	(0.09)
L5.				0.14	0.38***	0.16	0.21	0.27***	0.15
				(0.15)	(0.06)	(0.13)	(0.15)	(0.08)	(0.14)
L6.				0.07	0.08	0.33**	0.11	0.07	0.19**
				(0.11)	(0.06)	(0.13)	(0.11)	(0.06)	(0.08)
Ass. Prof Salary	0.07	0.02	0.35**	−0.02	−0.09	0.09	0.01	−0.07	0.17
	(0.11)	(0.16)	(0.14)	(0.14)	(0.07)	(0.13)	(0.13)	(0.07)	(0.1)
Obs.	405	387	361	126	121	116	124	123	118
Adju. R2	0.99	0.98	0.99	0.98	0.99	0.97	0.99	0.99	0.99
Joint F-stat for Prem.	95.03	728.5	8.94	3.72	9×10^4	24.75	6.51	15.17	66.99

Robust standard errors in parentheses.
Estimates of the university premiums are given in Appendix Tables A.4–A.6.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

examines the role of immigration on the high school completion of native students in the US. The study finds that the positive encouraging effects on high school completion of natives outweigh the discouraging effects. In contrast, the results from Gould, Lavy, and Paserman (2009), using the data on mass migration from the former Soviet Union to Israel in the early 1990s, show that the exposure to immigrants in elementary school had a substantial adverse effect on native students' high school matriculation results. Furthermore, Seah (2014) examines the effect of immigrant peers on the standardized test performance of native students and finds positive, insignificant, and negative effects in Australia, the US, and Canada, respectively.

Unlike the literature on immigrant peer effects on native elementary and high school achievements, there is a lack of studies on graduate degree completion. Zhang (2009), using the NSF's Survey of Earned Doctorates from 1966 to 2002, finds that the numbers of foreign and native doctoral degree recipients are positively correlated in Science & Engineering fields (S&E), but negatively correlated in non-S&E fields. Using similar dataset, Bound, Turner, and Walsh (2009) find that the large inflow of Chinese students into US Ph.D. programs in physical and life sciences in the 1980s caused no crowding out effect on native doctorate recipients. However, Zhang (2009) and Bound et al. (2009) examined the issue of crowding out and not that of externalities and they did not control for enrollments.

The presence of international students can affect graduate school completion rates through different channels. First, the completion rate is higher among international students motivated to finish their studies and join the US labor market.[1] Second, those returning to their countries of origin are typically under immense pressure to complete on time by their sponsoring agencies and to become better competitors in the home market. They may also cause an indirect effect on fellow native students through peer effect, reducing resource constraint, and displacement and wage effects in the labor market.

[1] For instance, 67% of foreign PhD students compared to 54% of domestic PhD students, complete their studies within 10 years (CGS, 2008).

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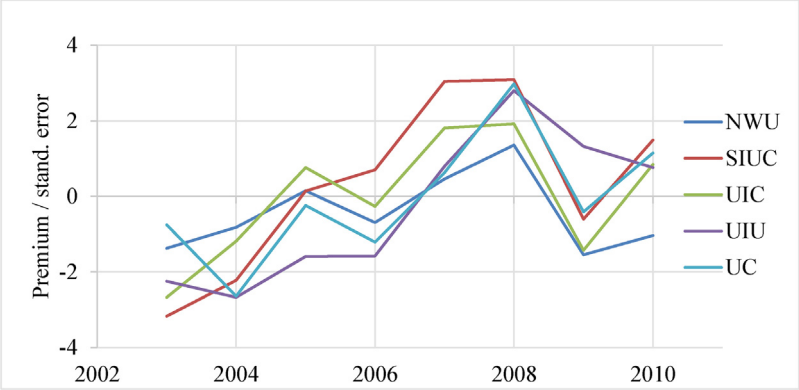

Fig. 1. PhD graduation premiums of selected universities in Illinois.

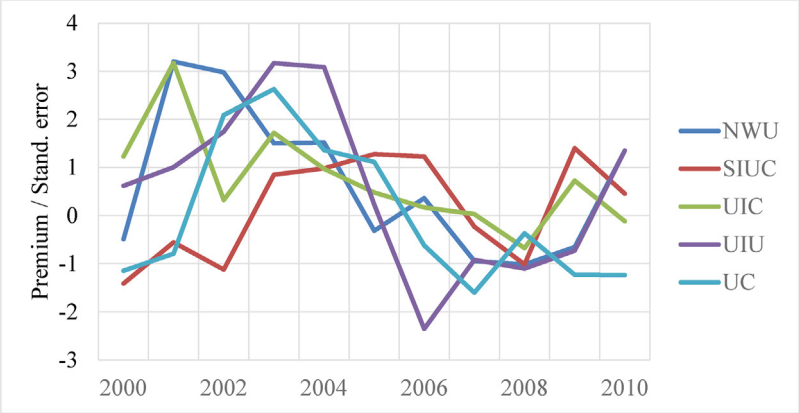

Fig. 2. Master's graduation premiums of selected universities in Illinois.

Many foreign students have scholarships or assistantships awarded on competitive bases. They work hard to achieve better grades to ensure the continuity of their financial support. As such, their presence in a given department may increase grade competition, academic discussion, and research that are likely to improve the success of all students. Besides, universities in the US charge international students, not on assistantships, a higher tuition. This helps universities to raise funding for native students, hire more professors, and invest in research. Further, the effect of international students in the labor market may encourage native students to continue and complete their studies. Grossmann and Stadelmann (2012) and Peri et al. (2014) find a significant increase in wages paid to college-educated natives because of the immigration of high-skilled workers. Skilled immigrants may bring new skills into the market, increase productivity, and create new products, which may increase the wages of native workers.

We analyze the impacts of international students on the performance of host universities and native students using data on enrollment and graduation – disaggregated by universities, programs, and types of students – for the states of Illinois and California, U.S.A. We follow two methods: a one-step method and a two-stage method. In the one-step method, we examine how international students affect the graduations of native students and of all students, separately for master's and PhD degrees, after controlling for enrollments and a number of program- and university-specific variables.

In the two-stage method, we use a concept of 'graduation premiums'.[2] A 'graduation equation' is given by the number of degrees conferred in a given discipline and university as a function of lagged enrollments, university indicators, and other discipline-level characteristics. After controlling for differences in enrollment and field effects, the coefficients for the university indicators capture the unexplained differentials in the discipline-level graduation numbers caused by university effects. Since enrollment differentials are controlled for, coefficients of the university indicators represent cross-university differences in degree completion. Accordingly, we define these coefficients as graduation premiums measuring how many more or fewer students graduate from a given university (averaged over disciplines) relative to the number of graduates from an averagely performing university in the sample. The premiums are estimated separately for each year.[3] In the sec-

[2] Our definition of premium is similar to that of the industry wage premium (Krueger & Summers, 1988; Kumar & Mishra, 2008). This concept has also been adopted in other contexts. For example, Burgess and Pande (2005) examine how rural banks is India affect the incidence of poverty.

[3] A graduation premium shows performance of a university in terms of the success of students completing their degrees. Graduate schools in the US are characterized by low completion rates, particularly among native students. According to the Council of Graduate Schools (CGS, 2008), 57% of doctoral students complete their studies within 10 years. Similarly, 60% and 66% of STEM master's students complete their studies within three and four years, respectively (CGS, 2013).

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ond stage, the premiums are pooled to create a panel data, and the proportion of foreign degree recipients is used as an explanatory variable to examine whether international students influence the premiums and generate externalities that affect students' performance.

The one-step method is more straightforward than the two-stage method. However, we prefer the two-stage method for two reasons. First, unlike the one-step, the two-stage has a higher chance of capturing peer effect. Estimating premiums as a function of the share of foreign graduates captures how an increase in the latter influences degree completion rates as measured by the premiums. The one-step method would have been an ideal model with cohort data tracking students until graduation. Second, the differences in the discipline-level graduation numbers across universities are noisier in the one-step method than the two-stage because the differences are averaged across programs in the latter case.

In both methods, we find that foreign students increase the performance of host universities with respect to the graduation numbers of all and native students. In the one-step method, the number of foreign graduates across disciplines and universities is positively associated with the numbers of graduate students, native and all, successfully completing their degrees. In the two-stage method, we find that the share of foreign graduates increases university graduation premiums of all and native students, suggesting that foreign students generate positive graduation spillovers. The rest of the paper is organized as follows: Section 2 explains the data and sources; Section 3 presents the empirical strategy; Section 4 discusses the results; and Section 5 provides some concluding remarks.

2. Data

The enrollment and graduation data for Illinois universities for the period 1996–2010 come from the Illinois Board of Higher Education (IBHE).[4] The data provide demographic characteristics of students and identify foreign students as non-resident aliens. We use the two-digit Classification of Instructional Programs (CIP), which has 47 broadly defined fields of study. For California, we find similar data from the archive of California Postsecondary Education Commission (CPEC) for the period 1982–2009.[5] CPEC provides the graduation and enrollment data for the University of California (UC) and California State University (CSU) systems. Since most universities in the California State University system have limited or no PhD programs, our analysis for California is confined only to master's. However, for Illinois, we analyze both master's and PhD degrees.

Table 1 presents summary statistics of the share of foreign master's and PhD graduates in Illinois, California, and all universities in the US based on data from the Integrated Postsecondary Education Data System (IPEDS).[6] The mean share of foreign PhD recipients is higher than that of master's recipients in the state of Illinois and the national statistics. Among the three fields of study, engineering has the highest share of foreign graduates, followed by mathematics and statistics, and social sciences. The share of foreign graduates shows no clear trend except for PhD in social sciences which increased from 20 percent in 2001 to 36 percent in 2009 among all degree-granting institutions in the US. Overall, Illinois has a higher share of foreign graduates above the national average in both master's and PhD degrees.

The enrollment data is based on the stock of total enrollments during the fall semester of each year while the graduation data is based on the total number of degrees conferred each fiscal year. To find the flow of new students (net enrollment) during the fall semester, we use the change in fall enrollments accounting for graduated students:

$$e_{ijt} = E_{ij,t} - (E_{ij,t-1} - G_{ij,t})$$

where e is the flow of new students, E is gross enrollment, and G is the number of graduates. The subscripts i, j, and t stand for discipline, university, and time, respectively. After cleaning inconsistent figures, the data for Illinois include 19 universities with PhD and 44 universities with master's programs, and the data for California include 29 universities with master's programs.[7] Enrollment data for the CSU system is not available for 2005 and 2006. Accordingly, for the period 2006–2009, we estimate premiums only for universities in the UC system.

University-specific variables such as research expenditure, number of faculty, and average faculty salary are collected from the IPEDS. Besides, we use average salaries of new assistant professors by two-digit discipline category from the College and University Professional Association for Human Resources (CUPA-HR).[8] CUPA-HR surveys faculty salaries for four-year colleges and universities and computes average salaries by discipline, rank, and tenure status. As a control for discipline characteristics, we use the salary for newly hired assistant professors averaged over the years 2008 to 2012.

3. Methodology

3.1. A two-stage method

This method follows the two-step industry wage premium methodology. The first step is a wage regression equation including workers characteristics and industry dummy indicators. Industry indicators capture wage differentials unexplained by individual worker characteristics. In the second stage, the industry wage premiums are regressed on other variables deemed to influence wage differentials across industries (Goldberg & Pavcnik, 2005; Kumar & Mishra, 2008).

The problem and structure of our data relate directly to the wage premium problem: wages there, graduation numbers here; individuals there, disciplines here; industries there, universities here. Therefore, we can directly apply the methodology here. We use enrollment and graduation data to estimate university graduation premiums for the total student population as well as for the native students. The industry wage premium indicates how much higher or lower an industry pays a worker relative to the average earnings of comparable workers across all industries. In the same way, the university graduation premium shows how many more or fewer students graduate from a given university (averaged over disciplines) – net of discipline level enrollments and field effects – relative to the average number of graduates of comparable disciplines across all universities in the sample. The first stage estimations of university graduation premiums involve a number of ordinary least squares (OLS) with a dependent variable representing the number of PhD (or master's) graduates across disciplines and universities. The independent variables include:

(i) Lagged new enrollments: are the main controls representing the numbers of students first enrolled some years back and

[4] http://www.ibhe.state.il.us/.
[5] http://www.cpec.ca.gov/.
[6] https://nces.ed.gov/ipeds/datacenter/.
[7] List of the universities for Illinois can be found in the Appendix Table A.1 and A.2, and universities for California can be found in Table A.3.
[8] http://www.cupahr.org/.

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Table 3
Correlation matrix of the actual and fitted number of graduates.

		California			Illinois					
		Master's recipients 2009			Master's recipients 2010			PhD recipients 2010		
		Observed	Fitted		Observed	Fitted		Observed	Fitted	
			LS	Poisson		LS	Poisson		LS	Poisson
	Least Squares (LS)	0.9953			0.9955			0.9944		
Fitted	Poisson	0.9302	0.9444		0.9227	0.9261		0.9695	0.9625	
	Nonlinear	0.9457	0.9551	0.9875	0.9531	0.9537	0.9528	0.9851	0.9836	0.9838

Table 4
VWLS results for the master's and PhD graduation premiums in Illinois – all students.

	Master's graduation premiums[a]				PhD graduation premiums			
	1	2	3	4	5	6	7	8
IR	0.360***	0.360***	0.269***	0.270***	0.129**	0.129**	0.141**	0.141**
	(0.058)	(0.058)	(0.066)	(0.066)	(0.060)	(0.060)	(0.060)	(0.060)
Res. Exp.	−0.041***	−0.041***			0.037***	0.037***		
	(0.011)	(0.011)			(0.010)	(0.010)		
Facu. Salary			−0.412***	−0.412***			0.223***	0.234***
			(0.037)	(0.037)			(0.047)	(0.049)
Facu._Grad		−0.003		−0.003		0.032		−0.096
		(0.009)		(0.009)		(0.119)		(0.123)
Public		−5.379***		.261		−20.313***		−12.137***
		(1.790)		(1.922)		(4.840)		(3.534)
Univ. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	480	480	438	438	148	148	148	148
Model $\chi 2$	3026	3026	2431	2431	817	817	808	807

Standard errors in parentheses.
*$p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
[a] We include dummy control for Trinity International University in the years 2000–2003 where the share of foreign graduates (IR) show very large fluctuations. But, the results are similar to those without this control.

Table 5
DGMM results for the master's and PhD graduation premiums in Illinois – all students.

	Master's graduation premiums[a]				PhD graduation premiums			
	1	2	3	4	5	6	7	8
Lag Prem.		0.302*		0.300*		−0.063		−0.077
		(0.172)		(0.175)		(0.147)		(0.136)
IR	0.831***	1.193*	0.967**	0.820	0.746**	0.693**	1.025***	1.080**
	(0.215)	(0.669)	(0.476)	(0.543)	(0.332)	(0.286)	(0.363)	(0.421)
Res. Exp.	−0.040	−0.034			0.023	0.035		
	(0.046)	(0.029)			(0.04)	(0.042)		
Facu. Salary			−0.573***	−0.410**			0.422	0.511
			(0.142)	(0.162)			(0.272)	(0.327)
Facu._Grad	−1.269	0.112**	0.156***	0.094**	−0.485	0.474	−2.125	−0.276
	(0.945)	(0.044)	(0.021)	(0.040)	(1.514)	(1.059)	(1.888)	(1.272)
Obs.	436	392	394	392	129	110	129	110
Instruments	20	37	20	37	8	14	8	14
Hansen P value	0.466	0.574	0.452	0.319	0.191	0.233	0.191	0.331

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
[a] As in the VWLS, we include dummy control for Trinity International University in the years 2000–2003.

may have stayed long enough to become potential candidates for graduation in their respective programs. The lag lengths are determined based on the general assumption that PhD programs may take three to six years for students who have master's degree, and it may take one to three years for master's students to complete their studies.[9] Overall, we expect coefficients of the lagged enrollments to be positive as they represent the common durations for the respective programs.

(ii) Average salary of new assistant professors by field of study as a control for discipline related heterogeneity. The rationale to

[9] Given the median duration of 7.7 years to complete a PhD program after having a bachelor's degree, those who have master's degree and enrolled in doctoral programs may, on average, need 3 to 6 years to complete their degree. Similarly, given the small increase in master graduation rates after 3 years of study as indicated in CGS (2013) for STEM programs, 1 to 3 years is long enough to obtain a master's degree for most students.

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Table 6
DGMM results for the master's graduation premiums in California – all students.

	(1)	(2)	(3)	(4)	(5)	(6)
Lag Prem.			0.184			0.175
			(0.15)			(0.118)
IR[b]	0.680**	0.727**	0.998*	0.542**	0.640**	0.894**
	(0.299)	(0.333)	(0.52)	(0.267)	(0.314)	(0.391)
Res. Exp.	−0.009	0.002	0.012			
	(0.016)	(0.018)	(0.036)			
Facu. Salary[a]				0.052	0.096*	0.106
				(0.046)	(0.054)	(0.075)
Facu._Grad		0.777***	1.050**		0.968***	1.160***
		(0.26)	(0.46)		(0.251)	(0.386)
Obs.	575	575	545	575	575	545
Instruments	20	21	20	20	21	20
Hansen P value	0.368	0.362	0.412	0.437	0.474	0.76

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
[a] Average faculty salary for the year 2000 is not available in the IPEDS. Since average faculty salary does not show large change in a given year, we use average of the 1999 and 2001 faculty salaries for the year 2000.
[b] UC Riverside is dropped in 1999 because the share of foreign graduates almost doubled, 17.1% in 1998 to 33.5% in 1999.

Table 7
Estimation results for the PhD graduation premiums in Illinois – native students.

	VWLS				DGMM			
	1	2	3	4	5	6	7	8
Lag Prem.						0.025		−0.025
						(0.18)		(0.168)
IR	0.186***	0.191***	0.175***	0.175**	0.877***	0.564**	0.815*	0.818**
	(0.068)	(0.068)	(0.068)	(0.068)	(0.195)	(0.218)	(0.421)	(0.323)
Res. Exp.	0.051***	0.051***			0.032	0.016		
	(0.009)	(0.009)			(0.03)	(0.031)		
Facu. Salary			0.272***	0.274***			0.373	0.304
			(0.045)	(0.047)			(0.24)	(0.235)
Facu._Grad		0.156		−0.017	0.177	0.467	−2.992	0.362
		(0.118)		(0.121)	(2.098)	(1.103)	(2.474)	(1.306)
Public		−29.625***		−15.946***				
		(4.712)		(3.498)				
Uni FE	Yes	Yes	Yes	Yes				
Obs.	148	148	148	148	129	110	129	110
Model $\chi 2$	696	695	690	690				
Instruments					8	14	8	14
Hansen P Value					0.154	0.272	0.235	0.179

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 8
DGMM results for master's graduation premiums in California – native students.

	(1)	(2)	(3)	(4)	(5)	(6)
Lag Prem.			0.321***			0.303***
			(0.123)			(0.104)
IR[b]	0.672***	0.725***	0.671	0.578***	0.666***	0.681**
	(0.234)	(0.26)	(0.413)	(0.218)	(0.245)	(0.27)
Res. Exp.	−0.013	−0.009	0.009			
	(0.012)	(0.013)	(0.028)			
Facu. Salary[a]				−0.011	0.021	0.032
				(0.042)	(0.051)	(0.066)
Facu._Grad		0.755***	1.113***		0.965***	1.090***
		(0.253)	(0.331)		(0.261)	(0.318)
Obs.	575	575	545	575	575	545
Instruments	20	21	20	20	21	20
Hansen P value	0.347	0.442	0.488	0.38	0.589	0.542

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.
[a] Average faculty salary for the year 2000 is not available in the IPEDS. Since average faculty salary does not show large change in a given year, we use average of the 1999 and 2001 faculty salaries for the year 2000.
[b] UC Riverside is dropped in 1999 because the share of foreign graduates almost doubled, 17.1% in 1998 to 33.5% in 1999

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Table 9
SGMM results for PhD graduations in Illinois.

	Total PhD Graduates				Native PhD graduates			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Foreign PhD Grad	0.788***	0.714***	0.714***	0.727***	0.278***	0.234**	0.237**	0.243**
	(0.154)	(0.154)	(0.151)	(0.152)	(0.095)	(0.098)	(0.098)	(0.093)
L3. New Enrol.	0.229***	0.233***	0.232***	0.240***	0.264***	0.268***	0.269***	0.271***
	(0.028)	(0.028)	(0.029)	(0.029)	(0.030)	(0.030)	(0.030)	(0.031)
L4. New Enrol.	0.274***	0.274***	0.274***	0.274***	0.318***	0.321***	0.321***	0.319***
	(0.031)	(0.031)	(0.032)	(0.032)	(0.029)	(0.029)	(0.029)	(0.029)
L5. New Enrol.	0.173***	0.177***	0.178***	0.172***	0.145***	0.144***	0.143***	0.142***
	(0.019)	(0.018)	(0.018)	(0.018)	(0.025)	(0.026)	(0.026)	(0.025)
L6. New Enrol.	0.208***	0.205***	0.206***	0.201***	0.213***	0.209***	0.209***	0.210***
	(0.025)	(0.024)	(0.025)	(0.025)	(0.032)	(0.032)	(0.032)	(0.032)
Research Exp.		0.072***	0.073***			0.038**	0.037**	
		(0.019)	(0.020)			(0.016)	(0.017)	
Facu. Salary				0.312***				0.124*
				(0.088)				(0.072)
Facu_Grad Ratio			−0.096	−0.187			0.094	0.034
			(0.207)	(0.205)			(0.171)	(0.175)
Public			−39.944***	−13.748**			−13.924**	−12.090*
			(8.924)	(6.003)			(5.954)	(6.264)
Uni. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	973	973	973	973	973	973	973	973
Instruments	76	97	98	98	76	97	98	98
Hansen P-values	0.797	0.461	0.446	0.574	0.95	0.478	0.406	0.564

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 10
SGMM results for master's graduations in California.

	Total MS Graduates				Native MS graduates			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Foreign PhD Grad	0.706***	0.722***	0.721***	0.723***	0.177*	0.189*	0.188*	0.189*
	(0.132)	(0.135)	(0.135)	(0.137)	(0.104)	(0.106)	(0.106)	(0.107)
Research Exp.		0.016***	0.016***			0.020***	0.019***	
		(0.005)	(0.005)			(0.004)	(0.004)	
Facu. Salary				0.097***				0.090***
				(0.018)				(0.017)
Facu_Grad Ratio			−0.144**	(0.104)			−0.136**	−0.114*
			(0.070)	(0.069)			(0.067)	(0.067)
L1. Net Enrol.	0.187***	0.187***	0.187***	0.188***	0.195***	0.195***	0.196***	0.196***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.015)	(0.015)	(0.015)	(0.015)
L2. Net Enrol.	0.285***	0.283***	0.283***	0.282***	0.288***	0.286***	0.286***	0.285***
	(0.016)	(0.016)	(0.016)	(0.016)	(0.018)	(0.018)	(0.018)	(0.018)
L3. Net Enrol.	0.220***	0.221***	0.221***	0.221***	0.227***	0.229***	0.229***	0.230***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.013)	(0.013)	(0.013)	(0.013)
Uni. FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Field FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7420	7412	7412	7412	7420	7412	7412	7412
Instruments	280	483	484	472	280	483	484	472
Hansen P-values	0.229	0.972	0.951	0.799	0.326	0.968	0.962	0.831

Robust standard errors in parentheses.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

include the salary of new assistant professors is that fields of studies with higher rates of return may face higher graduation rates. Students with career paths in such fields may be motivated to complete their study sooner than later because of the opportunity costs involved in quitting prematurely or delayed graduation. Accordingly, we expect the average salary of assistant professors to be positively associated with the number of graduates. The alternative to this variable is to incorporate field fixed effects, which increases the number of controls substantially in addition to the university fixed effects.

(iii) University indicators: university fixed effects control for the graduation effects of university characteristics leading to over or underperformance in terms of graduation rates. Coefficients of the university indicators represent 'graduation premiums', reflecting the graduation differentials – net of discipline-level lagged enrollments and field effects – across universities.

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Table A.1
Institutions included in estimating master's graduation premiums in Illinois.

Argosy Univ. Chicago Campus	Lewis University	Rush University
Aurora University	Lincoln Christian University	School of the Art Inst. Chicago (SAIC)
Benedictine University	Loyola University of Chicago	Southern Illinois Univ. Carbbondale (SIUC)
Bradley	Midwestern University (MWU)	Southern Illinois Univ. Edwarsville (SIUE)
Chicago State University (CSU)	National-Louis University (NLU)	St. Xavier University
Columbia College Chicago (CCC)	North Central College	The John Marshall Law School (John M.)
Concordia University	North Park University	Trinity International University
DePaul University	Northeastern Illinois University (NEIU)	Univ. of Illinois at Chicago (UIC)
Dominican University	Northern Illinois University (NIU)	Univ. of Illinois at Springfield (UIS)
Eastern Illinois Univ. (EIU)	Northwestern University (NWU)	Univ. of Illinois at Urbana/Champaign (UIU)
Elmhurst College	Olivet Nazarene University	University of Chicago (UC)
Governors State University (GSU)	Quincy University	University of St. Francis
Illinois Institute of Technology (IIT)	Rockford College	Western Illinois University (WIU)
Illinois State University (ISU)	Roosevelt University	Wheaton College
Lake Forest College	Rosalind Franklin Univ. of Medicine	

Table A.2
Institutions included in estimating PhD graduation premiums in Illinois.

Benedictine University	Northwestern University (NWU)	Chicago School of Prof. Psychology (CSPP)
DePaul University	Roosevelt University	The John Marshall Law School (John M.)
Illinois Institute of Technology (IIT)	Rosalind Franklin Univ. of Medicine	University of Illinois at Chicago (UIC)
Illinois State University (ISU)	Rush University	Univ. of Illinois at Urbana/Champaign (UIU)
Loyola University of Chicago	Southern Illinois Univ. Carbondale (SIUC)	University of Chicago (UC)
Midwestern University (MWU)	Southern Illinois Univ. Edwardsville (SIUE)	Wheaton College
Northern Illinois University (NIU)		

Consequently, the first stage OLS graduation regression equation is defined as:

$$G_{ijt} = \alpha + \sum_{k=l}^{q} \beta_k e_{ij,t-k} + \beta_w w_i + \sum_{j=1}^{M} GP_{jt} U_j + \epsilon_{ijt}, \quad (1)$$

where G_{ijt} is the number of degree recipients, $e_{ij,t-k}$ denotes k years – 3 to 6 for PhD and 1 to 3 for master's – lagged enrollments of new students, and U represents institutional dummy indicators with the coefficients GP_{jt} capturing university graduation premiums in each period. The subscripts i, j, and t stand for discipline, university, and time, respectively. Besides, w_i is the average salary of new assistant professors by fields of study controlling for discipline related heterogeneities.[10]

With a set of dummy indicators in a regression, the standard procedure is to drop one category and compare the resulting differences relative to the base category. However, as noted in Haisken-DeNew and Schmidt (1997), such specification may not represent a good economic interpretation in many circumstances. For instance, Krueger and Summers (1988) estimated industry wage differentials as deviations from an employment-share weighted mean.

In this study, to keep all the universities and compare the premiums relative to an average, instead of a base category, we use enrollment shares as a weight.[11] As a result, the premiums represent proportional differences in the number of graduates across universities at a discipline-level relative to the enrollment-share weighted mean graduation numbers. An averagely performing university would have a premium, neither positive nor negative, reflecting the fact that the number of graduates in a given discipline of the university is the same as the average number of graduates across all the disciplines in the sampled universities with comparable lagged enrollments and discipline effects. For instance, if the graduation premium of a university is positive two, it implies that a given discipline in the university would have on average two extra graduates than the average number of graduates among comparable disciplines across all universities after accounting for lagged enrollments.

Standard errors of the normalized graduation premiums are calculated using the Haisken-DeNew and Schmidt (1997) two-step restricted least squares procedure with the weighted sum of the premiums restricted to equal zero:

$$\sum_{j=1}^{M} GP_{jt}.\lambda_{jt} = 0 \quad (2)$$

where the weight, $\lambda_{jt} = \sum_i E_{ijt} / \left(\sum_j \sum_i E_{ijt}\right)$ is university j's share in the total enrollment of all universities in the sample at time t.

In the first stage, we adopt a cross-sectional estimation separately for each year to estimate the annual graduation premiums of the universities. Estimation of the premiums over time could be done using a panel data approach by creating interaction terms between university and year indicators. However, the interaction terms may capture not only university effects but also time effects. The cross-sectional approach better serves our objective to estimate the annual premiums in the first stage after controlling for discipline-level lagged enrollments and field effects, and use time-varying university-level variables in the second stage to examine factors that affect the university premiums. Besides, the enrollment shares used to normalize the premiums would not be constant over time. It would be difficult to create a constraint for the enrollment share-weighted coefficients of the interaction terms between the university and time indicators. For these two reasons, we use a cross-sectional estimation separately for each year in the first stage of the two-step method.

In the second stage, we pool the university graduation premiums over time to form a panel dataset. Next, a regression equation is formulated with the premiums as a dependent variable and the following explanatory variables:

(i) Share of foreign graduates: the share of international PhD (or master's) graduates is used to capture externalities generated by foreign graduates that would affect the degree completion rates of native and all students in a program. Coefficients of this

[10] Using discipline dummy indicators as controls for discipline related heterogeneities, we find similar results. To reduce the number of dummy variables, our final estimates use salary of new assistant professors.

[11] Enrollment shares are calculated for each university in the total (PhD or master's) enrollments across all universities and disciplines in the sample.

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Table A.3
Partial results of the master's graduation equation in California.

Dependent Var: Degree Granted	Total						Native					
	2009	2005	2000	1995	1990	1985	2009	2005	2000	1995	1990	1985
New Enrollment												
L1.	0.17**	0.15	0.29***	0.37***	0.36***	0.43***	0.15**	0.35***	0.29***	0.33***	0.36***	0.46***
L2.	0.51***	0.41***	0.26***	0.27***	0.10***	0.18**	0.55***	0.13**	0.24***	0.26***	0.10***	0.17*
L3.	0.32***	0.41***	0.37***	0.34***	0.48***	0.33***	0.32***	0.51***	0.38***	0.41***	0.46***	0.29***
Ass. Prof. Salary	−0.23	0.07	0.30***	0.32*	0	0.16	−0.23*	−0.11	0.25***	0.29**	−0.06	0.17
Premiums												
Cal Poly San Luis Obispo		−8.05*	−0.58	−8.19*	3.04	−3.82		−6.51	−0.62	−8.07**	3.63	−3.31
Cal State Poly Pomona		−3.34	−4.07	−5	−2.8	1.05		0.74	−1.72	−4.3	−2.7	8.55
CSU Bakersfield		4.75	2.06	−5.97*	−15.47**	−5.98***		5.02	1.52	−5.67	−10.81**	−4.55***
CSU Chico		1.7	−1.62	−10.66***	5.49	−2.25		−0.03	−1.08	−8.82***	4.69	−2.46
CSU Dominguez Hills		7.29**	4.16	11.25	6.12	−1.73		6.37	5.02	10.71	0.09	−3.13
CSU East Bay		0.78	2.06	3.02	6.05	5.2		1.58	−0.89	2.57	5.21	6.67
CSU Fresno		11.39**	−1.87	3.33	2.83	3.42		15.80**	−1.62	3.58	3.40*	3.19
CSU Fullerton		−4.32	2.79	0.18	−9.46***	−1.07		−8.39***	2.7	0.01	−9.09***	0.25
CSU Long Beach		14.61*	1.41	15.01**	−11.20**	−2.82		7.32	1.72	13.89**	−10.61**	−2.24
CSU Los Angeles		−9.45*	0.02	−13.03***	−5.57	−3.73		−21.00***	0.13	−11.31***	−4.85	−3.12
CSU Monterey Bay		4.49						2.35				
CSU Northridge		−1.81	3.37	4.27	−3.11	−1.41		3.34	2.35	3.2	−2.29	−1.46
CSU Sacramento		1.63	−3.16	6.11	−3.84	−1.01		2.28	−2.43	6.2	−2.45	0.22
CSU San Bernardino		−2.75	−5.21	−11.91***	8.58	−7.61*		−1.6	−4.31	−10.15***	4.34	−7.38*
CSU San Marcos		−7.61	−30.03***					−4.75	−30.71***			
CSU Stanislaus		3.79	0.35	−3.81	−4.47	−4.89		8.34	0.8	−3.42	−3.49	−2.95
Humboldt State Uni.		0.08	−2.74	−8.69*	3.56	−3.43		4.09	−2.62	−6.26	3.34	−1.33
San Diego State Uni.		−7.62	1.09	5.55	8.05*	0.92		−1.45	0.98	4.38	5.93	0.19
San Francisco State Uni.		1.15	−3.27*	0.42	−1.29	4.33		−0.24	−2.33	1.11	0.08	4.37
San Jose State Uni.		−4.87	−1.45	−1.28	−0.54	−2.6		−12.49**	−0.72	−3.97	−0.93	8.28**
Sonoma State Uni.		−1.11	0.7	−4.11	2.54	−4.18		0.76	1.16	−3.72	2.35	−3.33
UC Berkeley	−3.24	1.57	4.50**	−12.10***	3.81	1.99	−2.14	10.14***	3.33	−11.21***	5.03	2.68
UC Davis	−4.7	3.39	−4	−2.36	4.45**	−5.50**	−1.91	5.90**	−5.7	−2.5	3.73*	−4.75**
UC Irvine	8.64**	7.39*	−1.53	−5.05	3.75	−3.97	6.18*	9.69**	−3.77*	−5.34	3.01	−3.05
UC Los Angeles	−1.6	−4.34	6.91	−11.56**	7.82*	−1.63	−1.78	2.22	7.76	−9.03*	8.94**	−2.32
UC Riverside	6.41*	3.88	−4.78***	−0.68	7.11**	−2.05	5.56	4.61	−4.30**	−1.16	6.73***	−2.92
UC San Diego	5.31*	0.81	−3.11	−1.48	2.28	0.92	4.36*	4.83	−4.24**	−1.89	2.79	0.86
UC Santa Barbara	−0.34	5.42**	−3.78*	−2.52	5.61*	2.67	−1.59	6.12**	−5.50**	−2.89	4.68*	0.72
UC Santa Cruz	−2.58	1.2	−3.57*	−2.02	3.4	0.58	−1	2.76	−3.87**	−1.67	4.80*	−0.05
Constant	14.31	−3.55	−12.93**	−14.98	0.19	−6.58	12.97*	4.33	−9.86*	−13.68*	3.07	−6.96
Obs	92	370	358	349	315	288	92	370	358	349	315	288
Joint F for Prem.	2.44***	2.02***	5.63***	2.78***	2.02***	1.32	2.00*	2.60***	10.45***	2.47***	2.14***	1.52*

Standard errors are robust.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

variable reflect the association between an increase in the share of foreign graduates and the relative performance of a university in terms of its graduation premiums. A positive coefficient reveals externalities generated through peer effects, resource mobilization, and labor market effects that would increase the degree completion rates. On the other hand, a negative coefficient may reflect possible adverse effects of foreign students that would increase dropouts and delayed graduations.

(ii) Research expenditure and average faculty salary: universities with a higher investment in research and faculty would be able to attract highly qualified students and faculties. With such resources, graduate students will be able to acquire better assistantships and scholarships that would reduce their financial burdens and make them focus on their academics. Besides, students will get opportunities to work with highly qualified scientists in research centers and laboratories equipped with the necessary resources and technologies. In effect, such opportunities offer students a higher potential for successful completion of their degrees and competitive edge in the labor market which may affect the graduation premiums positively. In contrast, demanding course works and research requirements among the top tier research universities may lead to higher dropouts and longer study durations associated with lower graduation premiums.

(iii) Faculty to graduate students ratio: the time that faculty spend supervising graduate students, whether talking about research or course work, may boost the productivity and success of students. As a result, a higher faculty-student ratio may produce a positive effect on graduation premiums as students benefit from increased faculty supervision. It is also possible that faculty may spend less time supervising students and more time doing research and searching for grants. In this case, a higher faculty-student ratio may not increase the completion rates of graduate students. For instance, Brewer, Douglas, Facer, and O'Toole (1999) find a negative but insignificant relationship between faculty – student ratio and graduate research productivity.

(iv) State ownership indicator: university ownership structure – state versus private – may influence graduation rates across universities.[12] Private universities tend to have higher tuition fees, lower class sizes, and more per capita resources than

[12] Public – private distinction is only available for Illinois universities. All universities are public in the sample for California.

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Table A.4
Estimated master's graduation premiums among the total students in Illinois.

	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
Argosy	56.113***	−19.777**	3.556	−18.765***	−2.252	15.217***	5.954	6.348	−5.9	−46.347***	
Aurora	−10.86	−29.195	−13.739	−22.388	−13.933	−16.125	10.078	−18.131	−10.985	6.006	8.34
Bene.	14.269*	−5.744	−20.526	4.298	10.3	21.772*	5.296	15.987*	7.993	20.202*	2.412
Bradley	−0.323	2.533	−5.506**	0.441	12.586	5.751*	5.89	3.425	0.086	9.489***	0.773
CSU	0.699	5.238	4.492	−7.493*	2.991	4.308	3.347	5.222	8.143	4.285	−2.942
CCC	8.989	5.755*	1.02	−4.622	−2.17	0.172	−0.548	−4.304	2.378	14.634***	9.999
Conco	−1.206	6.115	18.966	−20.202	−10.049	−17.108	13.585*	10.875	2.019	6.807**	−8.925
DePaul	2.568	8.238	2.092	−9.447**	−2.663	3.58	5.058	1.478	−2.788	16.469*	5.42
Domin.	−6.592	−5.016	25.849***	23.785**	11.319**	−16.153	−8.622	0.215	−6.061	−13.38	−15.096***
EIU	3.458	1.414	−3.024	−5.164*	−3.987*	5.671*	7.624	2.498	2.735	9.024***	2.055
Elmhurst	3.776	0.362	1.732	−5.686**	−0.803	4.594*	4.16	0.539			
GSU	−16.26	−3.525	8.117	17.651	6.289	1.845	5.665	10.125	−9.677	10.999***	4.859
IIT	0.85	20.566**	−2.879	−12.009*	−0.983	17.103***	14.969**	2.761	−9.809	0.346	3.118
IST	−2.099	1.513	−1.867	−3.844	1.76	6.147**	5.659	7.623	3.183	7.288*	0.374
Lake F.	3.124**	−2.794	−4.586**	−4.725*	6.869***	3.414	3.676	4.778	3.685	13.217***	1.699
Lewis	−6.64	−3.342	1.291	4.774	−18.589**	1.378	7.332*	10.083	0.445	5.532**	4.726
Lincoln C.U.	15.122***	1.545	−10.516***	−19.614***	−18.585***	−20.067***	−11.855***	−9.524**	11.179**	3.466	14.118***
Loyola	−10.577*	−6.111	6.462	−1.571	1.502	7.37	7.353	6.894	8.178	10.140***	5.57
MWU	0.959	5.613	−3.502	−18.429*	11.833	6.081**	−10.978***	8.469**	27.653***	24.089***	−38.378***
NLU	19.346*	29.635	−5.505	46.656	2.203	−53.850*	−140.508***	−145.565**	−88.402	−94.637***	−21.903
North C.	1.627	4.405	1.445	1.23	−2.823	7.608	11.703	8.883	−32.255**	−20.974**	−0.11
North P.	−10.332	−2.062	−9.001	3.868	−0.441	−0.456	−4.383	7.515	−4.275	−1.872	−0.637
NEIU	2.857	1.713	−0.723	0.763	0.689	3.950*	0.222	4.37	0.674	5.806**	2.2
NIU	8.686	1.952	1.603	−1.065	6.554	4.206	1.309	1.562	7.021	6.345**	2.222
NWU	3.361	−2.132	−5.698	−5.631	2.548	−1.508	16.679	9.024	18.099***	12.007***	−3.312
Olivet	−1.946	−16.978	−2.546	−10.357	32.681	27.119**	−2.765	1.856	25.925	−34.448	9.106
Quincy	−1.635	8.689*	13.985**	−7.395	−6.174	−0.281	−9.089	−25.997***	−37.163***	15.430***	49.777***
Rockford	−97.554***	−58.010***	−12.105**	41.752***	9.102	1.52	40.786***	102.853***	10.552***	45.306***	56.763***
Roosevelt	4.98	1.062	−2.766	2.306	−3.790*	8.921**	−0.423	0.357	3.971	13.857**	9.560**
Rosalind	4.425	3.527	22.455**	4.33	−9.875	4.076	6.226	10.305	12.356**	6.458***	8.892
Rush	−4.877	−13.265	0.028	−10.452	−6.374	−17.679	5.813	4.711	5.45	5.696**	−5.307
SAIC	−6.849	−3.77	−6.641**	0.782	7.746**	3.009	12.327	−0.698	8.681	5.579	5.751
SIUC	0.996	4.417	−2.198	−0.689	2.816	3.651	4.056	4.128	−5.594	−2.485	−3.066
SIUE	−2.213	−1.177	4.112*	1.741	1.967	2.212	3.137	8.433*	0.53	4.827	0.8
St. Xavier	−18.07	−10.899*	−3.864	27.083	−5.099	−14.805	10.358	11.36	20.883**	4.716	−5.591
John M.	−21.075***	−13.745	12.662	1.465	32.354***	2.003	−8.207	−19.798***	4.055	8.989**	3.493
Trinity	9.327***	−16.408**	0.593	−20.290*	−21.976	1.468	22.541	36.161*	9.366	−6.494***	11.708**
UIC	−0.539	2.127	−2.381	0.133	1.167	2.118	5.266	8.962*	1.705	10.641***	8.023
UIS	−6.629	2.386	21.781	−9.480**	3.771	9.373**	4.34	0.163	3.196	10.528**	1.656
UIU	5.741	−2.96	−3.819	−5.215	−9.175**	0.912	16.812***	27.258***	13.074*	3.292	2.61
UC	−4.442	−5.848	−1.87	−8.074	−3.314	6.564	9.956	18.782***	21.396**	−4.068	−6.443
St. Francis	2.394	−12.154	1.202	12.635**	32.241	19.844	51.747	2.46	−17.865	−24.921***	−31.911
WIU	6.036**	1.86	−2.194	−4.875	−9.499	0.855	4.348	9.802	1.226	9.006*	4.218
Wheaton	−2.19	−7.039**	−2.607	2.942	−2.554	12.154***	10.688	6.912	10.752	10.144***	−11.752*
N	405	409	387	378	371	363	361	359	355	358	362
Joint F Stat	95.03	20.24	53.03	728.5	1670.94	578.12	8.94	356.04	617.44	7844.16	1167.36

Standard errors, not reported here, are robust.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

public universities. Besides, students could benefit from frequent one-on-one access to professors, and a closer relationship with each other and university administration. With a higher tuition burden and strong community support, students would have a higher motivation to graduate on time. This may lead to improved graduation efficiency among private universities expressed in terms of higher graduation premiums.[13]

(v) University fixed effects: apart from the observed university characteristics that are presumed to affect the graduation premiums, unobserved time-invariant characteristics, such as reputation, may influence the premiums. We control for such effects through the university fixed effects.

Accordingly, the second-stage regression equation of the premiums is defined as:

$$GP_{jt} = \alpha + \gamma \mathrm{IR}_{jt} + Z'_{jt}\beta_z + U'_j\beta_u + e_{jt}, \quad (3)$$

where IR_{jt} is the share of international graduates (across all disciplines included in the first stage regression), the vector Z_{jt} represents observed university-level characteristics, and the vector U_j captures university fixed effects.

The dependent variable, GP_{jt}, is compiled from the first stage estimations. The measurement error due to the standard errors in the first stage does not affect the consistency of the second-stage coefficients but introduces additional noise to the model which increases the variance of the coefficients (Goldberg & Pavcnik, 2005). To account for this noise, we adopt a variance-weighted least squares (VWLS) using the inverse of standard errors of the premiums as weights. This gives more emphasis to the premiums with lower variations than those with higher variations so as to reduce the noise.

[13] For instance, the six year graduation rates for students who enrolled for the first-time in fall 2010 to seek undergraduate degree was 59% at public institutions and 66% at private nonprofit institutions (McFarland et al., 2018).

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The fixed effects model fails to account for endogeneity between the graduation premiums and the proportion of foreign degree recipients that may arise due to unobserved time-varying factors. To address the possibility of such endogeneity issue, we use the difference generalized method of moments (DGMM) proposed by Arellano and Bond (1991) that recognizes the challenges we face to find external instruments. This method tries to control for endogeneity using internal instruments from within the model by taking the first difference of the regression equation and use lagged values of the level endogenous variables as instruments.[14]

3.2. A one-step method

In this method, we estimate a single equation combining variables from the first and second stages of the two-stage approach. The dependent variable represents the total (or native) degree recipients across disciplines and universities, the same as in the first stage (Eq. (1)) of the two-step method. The independent variables include the number of foreign graduates, lagged new enrollments, university characteristics, such as research expenditure, average faculty salary, faculty – graduate students ratio, and state ownership, and discipline (instructional category) fixed effects. Coefficients of the number of foreign graduates capture the association between the total (or native) and foreign graduation numbers over time across disciplines and universities.[15] The one-step regression equation is defined as:

$$G_{ijt} = \alpha + \sum_{k=l}^{q} \beta_k e_{ij,t-k} + \beta_f G^f_{ijt} + X'\gamma + e_{ijt}, \quad (4)$$

where G is the number of total (or native) degree recipients, G^f is the number of foreign degree recipients, e represents lagged enrollments (3–6 and 1–3 years for PhD and master's, respectively), and the vector X include university-level controls. We also include fixed effects to account for unobserved institution and discipline heterogeneities. Unlike the cross-sectional estimations separate for each year that we adopt in the first stage regressions of the two-stage method, a panel data approach is employed for this equation. Besides, we adopt the Blundell and Bond (1998) and Arellano and Bover (1995) System GMM to control for possible endogeneities that arise due to unobserved factors affecting the numbers of total (or native) and foreign graduates simultaneously.[16]

4. Results and discussion

4.1. Results from the two-stage method

4.1.1. Estimation of graduation premiums

In the first stage, we estimate university master's and PhD graduation premiums for the total student population. We also estimate graduation premiums for the native PhD students in Illinois and native master's students in California in Section 4.1.4. The first stage regressions of Eq. (1) estimated separately for each year specifies the number of graduates in a given year as a function of lagged new enrollments and university fixed effects.

Estimation results of Eq. (1), presented in Table 2 for the universities in Illinois, show significantly large coefficients of the lagged new enrollments. For master's, the 2-year lagged enrollment has the largest coefficient followed by the 3-year and 1-year lagged enrollments. This, as we expect, implies that master's students require on average 2 years to graduate. For instance, in the year 2007, 53% of master's graduates were those newly admitted to their respective programs in the fall 2005 (2-year lag), suggesting that these students graduated within four semesters. The rest of the graduates were admitted in fall 2006 (26%) and fall 2004 (19%).[17] Similar results are observed for PhD where the 3-year and 4-year lagged enrollments are always significant, whereas the 5-year and 6-year lags are significant in some cases. Overall, more than half of the PhD graduates in each year were admitted three to four years prior to their graduation.

The estimated graduation premiums show wide dispersion across universities and over time.[18] The joint F-statistics of the premiums implies that they are jointly significant at one percent level in all years and many of them are individually significant as well. Fig. 1 shows the trend of PhD graduation premiums of selected universities, University of Chicago (UC), Northwestern University (NWU), University of Illinois at Urbana/Champaign (UIUC), University of Illinois at Chicago (UIC), and Southern Illinois University Carbondale (SIUC). These premiums, normalized by dividing to their standard errors,[19] fluctuate around zero, which is the average premium across all the universities.

A graduation premium is positive when a university achieves higher graduation efficiency, and it is negative when the graduation efficiency of the university is below average. In many cases, the premiums may be insignificant reflecting the fact that a university has an average graduation performance compared to the other institutions in the sample. For instance, the PhD graduation premiums of UIC and NWU in 2008 were 4.7 (with a standard error of 2.5) and 2.9 (with a standard error of 2.1) graduates, respectively, as provided in Appendix Table A.5. While the former is significant, the latter is not. These values suggest that a given discipline (instructional category) in UIC had on average about 5 more graduates than a comparable discipline in NWU with similar enrollment statistics 3–7 years ago and similar field effects. Overall, Fig. 1 reveals two scenarios: (i) the premiums of the five universities presented seem to move together, and (ii) none of the universities maintained negative or positive premiums throughout the period. Finally, similar to the PhD graduation premiums, Fig. 2 reveals high fluctuations and co-movements in the master's graduation premiums.

The estimation of graduation premiums among the Californian universities is performed only for master's.[20] Partial results of the first stage regressions and the estimated university master's graduation premiums are reported in Appendix Table A.3. As in the case of Illinois, the results indicate that all the lagged enrollment variables are significant determinants of graduation. The joint F-statistics indicates that the premiums are jointly significant in most years with many of them individually significant.

In addition to the constrained linear regressions, we tried other estimation techniques, Poisson count data and nonlinear regressions, and compared distributions of the fitted and actual values of the dependent variable. Count data regression helps to account for the fact that the dependent variable, number of graduates,

[14] We use DGMM to estimate Eq. (3) because the number of observations are small and the number of instruments become larger than the number of groups (universities) even when we use one lag of the endogenous variable as an instrument.

[15] Unlike the share of foreign graduates in Eq. (3) of the premiums regression equation, we use here the number of foreign graduates to investigate the direct association between the graduation numbers.

[16] System GMM is applicable in Eq. (4) because the dataset is large due to the university, discipline, and year dimensions of the data.

[17] Although coefficients of the three lagged enrollment variables summed approximately to one, it does not mean that all master's students graduate within three years. Coefficients of the lagged enrollment variables only reflect what fraction of graduates in a particular fiscal year was admitted in each of the preceding fall semesters, but does not reflect graduation rates.

[18] Tables A.4–A.6 in the Appendix contains the estimated master's and PhD premiums separately for the total and native students in each program.

[19] These are basically the t-statistics of the premiums, reflecting their significance.

[20] The reason for considering only masters programs has been given before: the California State university system have only a handful of doctoral programs.

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is discrete (Winkelmann, 2013). Similarly, we apply a nonlinear regression using exponential distribution to evaluate if exponential distribution fits the observed data better than the normal distribution assumption of the linear model. Table 3 presents the correlation matrix of the observed and fitted number of graduates. For Illinois (master's and PhD) in 2010 and California (master's) in 2009, the correlation coefficients are large, particularly between the linear prediction and the actual values. The linear model provides a more resembling distribution of the number of master's and PhD graduates and clearly outperforms the other two techniques. Accordingly, we adopt the linear regression to estimate the premiums in the first stage.

4.1.2. Graduation premiums and foreign students in Illinois

In the second stage regressions, we apply variance-weighted least squares (VWLS) and difference generalized method of moments (DGMM) in Eq. (3). The independent variables include share of foreign graduates (IR), research expenditure (Res. Exp.), average 9-month equivalent faculty salary (Facu. Salary), ratio of faculty to total graduate students (Facu._Grad), dummy indicator for public universities, and university fixed effects. We use the standard errors of the estimated premiums as weights to give more emphasis to the significant premiums than the insignificant ones.

4.1.2.1. Variance-weighted least squares estimation of the premiums. The VWLS estimation results for the master's and PhD graduation premiums are presented in Table 4. The dependent variable is the graduation premium among the total master's students in columns 1–4 and among the total PhD students in columns 5–8. We use research expenditure (in columns 1, 2, 5, & 6) and average faculty salary (in columns 3, 4, 7, & 8) as time-varying controls for university characteristics. Faculty to total graduate student ratio and a public ownership indicator are also included in columns 2, 4, 6, & 8.

Results in Table 4 suggest that one percentage point increase in the share of foreign master's graduates increases the master's graduation premium among the total students by about 0.3 graduates; an average of the 0.36 and 0.27 graduates when using research expenditure and average faculty salary as university quality measures, respectively. Similarly, PhD graduation premiums increase by about 0.13 graduates as a result of a percentage point increase in the share of foreign PhD recipients.

University quality indicators, research expenditure and average faculty salary, are associated negatively with the master's and positively with the PhD premiums. Research universities with a higher pay for faculty prioritize innovation and production of knowledge by attracting highly qualified students skilled to design and develop different scientific research projects. While such universities would be highly efficient in the production of doctorates, other universities with relatively lower spending on research and faculty would be efficient in master's programs. The VWLS results also suggest that public universities have lower premiums than private universities in both master's and PhD programs. This may arise for two reasons. First, the availability of generous assistantships and scholarships in private universities might attract better-qualified graduate students. Second, students without financial support would try to graduate quickly to save on the higher tuition of private universities.

4.1.2.2. DGMM estimation of the premiums. The DGMM results, reported in Table 5, correct for endogeneity using lags of the share of foreign graduates as instruments in the first difference equation. The lags are chosen in such a way that the number of instruments does not exceed the number of groups (universities). We use two and three years lag for master's and two years lag for PhD. Besides, lags of the dependent variable are also used as instruments in the dynamic regressions (columns 2, 4, 6 and 8), which include a lagged premium as a predetermined explanatory variable. Under the null hypothesis that the instruments are valid, the reported Hansen *p*-values show that they are orthogonal with the residual of the model.

Results suggest that the share of foreign graduates affects master's and PhD graduation premiums positively. One percentage point increase in the share of foreign graduates in master's and PhD programs increases university master's and PhD graduation premiums by about 1 and 0.7 graduates, respectively. As a result, disciplines in a university with such an increase in foreign degree recipients offer 1 more master's and 0.7 more PhD degrees than the average number of graduates in other universities. Further, the coefficient of faculty to graduate students ratio is significant and positive in the master's premiums implying that higher faculty-student ratio leads to higher master's graduates. Unlike the VWLS results, coefficients of research expenditure and faculty salary turn to be insignificant. Finally, the effect of public ownership is not included in these regressions because the DGMM technique takes the first difference of the variables.

4.1.3. Graduation premiums and foreign students in California

The second stage regressions for the premiums of Californian universities using DGMM are reported in Table 6.[21] [22] Results show that an increase in the share of foreign degree recipients is positively associated with the master's graduation premiums of all students. One percentage point increase in the share of international master's recipients increases the university graduation premium by more than 0.5 graduates. Comparing the effects in the two states, California and Illinois, we find similar positive effects on the total master's graduation premiums with a minor variation in magnitude. We also observe that faculty to graduate student ratio has a positive effect on the premiums, suggesting that a small class size or large faculty size produces higher graduation premiums.

Unlike the results for Illinois where the average faculty salary has a negative effect on the master's premiums, it is insignificant for the universities of California. This may be due to differences in the pool of universities and the study period between the two states. While both public and private universities are included in the Illinois data, the data for California covers only state-owned institutions. On the other hand, the length of the study period is much longer for California than for Illinois. We estimate master's graduation premiums from 1985 to 2009 and from 2000 to 2010 in California and Illinois, respectively, depending on the availability of lagged enrollment figures and institutional variables from the IPEDS database.

4.1.4. Graduation premiums among native students

In this section, we examine the externalities that foreign students generate toward their native counterparts. We estimate the effects of foreign degree recipients on the native graduation premiums for PhD in Illinois and master's in California in Tables 7 and 8 , respectively.

Results in Table 7 show a positive effect of international students on the native PhD graduation premiums across the universities in Illinois. One percentage point increase in the share of foreign doctoral recipients increases the PhD graduation premiums among native students by about 0.18 and 0.8 additional graduates in

[21] Due to the long panel structure of the data in these regressions, the count of instruments in the DGMM is too large even when we use one or two lags of the endogenous or predetermined variables as instruments. To reduce the number of GMM-style instruments, we use the *collapse* option in the *xtabond2* stata command (Roodman, 2009) to allow longer lag instruments.

[22] Similar to the case if Illinois, the Hansen overidentification tests suggest that the internal instruments are orthogonal with the residuals of the model.

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Table A.5
Estimated PhD graduation premiums among the total students in Illinois.

	2010		2009		2008		2007		2006		2005		2004		2003	
	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se
Bened	−5.363	7.11	6.49	4.21	0.792	4.4	4.051	4.02	−17.960**	7.23	16.644***	4.845				
DePaul	3.167	5.17	6.105**	2.99	−7.607	8.65	2.626	2.68	22.067	20.2	−15.345	11.33	−8.926*	5.11	−3.281	9.06
IIT	−6.622	5.67	−1.67	2.06	5.743***	1.99	7.919**	3.84	0.089	2.54	5.547	5.395	5.983	4.34	−7.009	4.7
ISU	10.205*	5.55	−1.369	1.94	5.255**	2.06	2.743	2.17	−0.183	4.66	1.573	3.534	−4.49	4.06	−3.947*	2.19
Loyola	0.587	3.11	6.048**	3.04	0.865	5.29	7.962***	2.3	1.735	3.48	7.275*	4.196	−0.223	3.86	−3.986*	2.27
MWU	0.654	12.4	−29.506***	8.02	−59.552***	10.4	−47.567***	6.38	−6.222	49.8	−11.849	30.14	27.327**	13.6	75.998***	5.1
NIU	−1.423	2.47	1.115	3.21	5.086*	2.96	0.434	3.06	−0.621	5.26	−0.732	4.641	0.408	1.83	2.094	2.6
NWU	−3.501	3.38	−2.2	1.42	2.93	2.16	0.794	1.72	−2.988	4.32	0.585	4.064	−1.809	2.22	−4.264	3.11
Roosevelt	−8.457	6.43	−2.728	2.91	6.697**	2.77	8.152***	1.14	6.668**	3.05	11.386***	2.516	−2.386	5.04	3.201	4.38
Rosalind	−0.892	6.64	10.002***	3.25	11.351***	4.19	4.064	6.91	−1.549	2.72	2.261	3.776	−13.05	9.84	4.712	8.14
Rush	−10.914	7.42	12.486	8.26	20.836***	6.09	6.342***	2.33	11.784*	6.66	4.676	6.349	1.371	6.47	−4.981	4.01
SIUC	4.013	2.69	−0.917	1.53	6.038***	1.95	5.998***	1.97	2.471	3.52	0.508	3.576	−6.070**	2.73	−7.504***	2.37
SIUE	−7.501	8.03	27.685***	5.56	−15.351**	6.68	7.495***	1.24	4.448	3.88	−2.797	3.557	−4.643***	1.56	−3.647***	1.34
CSPP	11.546*	6.91	12.938***	3.68	8.190*	4.4	−3.764	8.51	−12.505	15.8	3.08	16.15	−28.242***	9.48	−0.779	2.42
John M.	−16.754	20.4	−4.57	8.22	−34.039***	9.03	−20.448	14.4	69.322**	29.5	29.768	26.63	90.541***	11.5	7.905	5.96
UIC	2.853	3.37	−2.168	1.52	4.709*	2.45	5.644*	3.12	−0.802	3.05	2.441	3.208	−3.886	3.28	−4.585***	1.72
UIU	2.792	3.67	2.9	2.19	5.223***	1.87	2.078	2.61	−13.111	8.3	−8.316	5.227	−12.881***	4.82	−5.970**	2.65
UC	2.571	2.24	−0.887	2.17	6.304***	2.12	1.29	2.05	−7.428	6.13	−1.078	4.532	−6.380***	2.41	−2.909	3.86
Wheaton	4.718***	1.69	−5.706***	0.99	6.461***	1.69	3.288**	1.26	3.206*	1.81	−3.151	2.282				
N	126		123		123		121		124		122		116		122	
Joint F stat	3.72		604.79		8.33		9.10E+05		339.76		67.51		24.75		80.47	

Standard errors are robust.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table A.6
Estimated PhD graduation premiums among the native students in Illinois.

	2010		2009		2008		2007		2006		2005		2004		2003	
	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se	prem	se
Bened	−3.416	6.554	7.892*	4.272	3.678	3.75	9.643**	4.084	−16.437***	4.916	13.044***	4.153				
DePaul	0.92	4.576	5.211**	2.279	−3.561	4.639	3.484	2.532	17.871	15.843	−15.834	12.248	−9.784*	5.247	−3.437	8.186
IIT	−5.927	6.312	0.162	2.119	5.282**	2.093	8.463**	3.489	1.453	2.212	6.134	5.063	3.843	3.645	−8.652*	4.969
ISU	9.032*	5.328	0.137	2.069	2.458	2.735	3.202	2.368	1.758	3.683	4.124	3.286	−4.835	4.929	−8.152**	3.794
Loyola	−1.814	2.545	5.618*	2.854	0.766	4.896	8.858***	2.748	2.613	3.003	8.167**	3.663	−1.507	3.332	−5.646*	2.887
MWU	13.675	12.245	−36.087***	13.483	−37.438***	11.994	−48.860***	11.366	−29.951	30.489	−23.815	20.419	17.741	15.074	72.869***	5.091
NIU	−0.331	2.579	1.348	3.218	5.415**	2.464	2.896	2.28	−1.151	4.331	−0.293	4.771	−2.601	2.269	−0.089	2.483
NWU	−1.406	3.38	−1.595	1.303	2.809	1.888	0.513	2.122	−1.4	2.903	−0.032	3.635	−2.501	2.535	−5.866***	2.171
Roosevelt	−8.294	7.86	−1.44	3.007	4.447	2.72	7.996***	1.719	6.893***	2.41	10.818***	2.342	1.649	3.209	6.478***	2.248
Rosalind	−2.881	5.89	14.470***	4.458	12.092**	5.003	2.745	7.966	−4.147	4.585	−2.446	4.978	−12.691	8.888	6.768	11.498
Rush	−7.921	6.985	12.85	8.728	16.715***	6.14	5.826	5.198	9.769*	5.384	5.621	4.434	4.158	3.65	−6.245*	3.497
SIUC	3.691	2.83	−0.181	1.45	6.314***	1.849	7.892***	1.988	2.401	2.902	−0.331	2.805	−5.713**	2.267	−6.592***	1.862
SIUE	−3.157	8.776	28.441***	5.833	−26.406***	5.634	7.344***	1.483	4.498	3.011	−2.732	2.588	−5.932***	1.21	−4.560***	1.124
CSPP	8.899	8.528	14.393***	3.6	−0.665	5.838	−12.062	8.03	−6.978	7.921	6.477	11.094	−24.482**	10.974	−0.285	1.629
John M.	−26.672	23.078	−6.913	7.398	−33.010***	8.824	−13.783	14.078	42.871***	16.273	23.387	19.508	73.794***	10.422	6.297	5.72
UIC	1.882	3.87	−0.881	1.866	4.374**	1.961	6.566***	1.94	0.125	3.19	2.418	2.6	−2.17	2.424	−5.007***	1.747
UIU	3.338	2.959	3.217	2.051	4.777***	1.781	2.577	2.598	−6.028	4.354	−2.171	3.434	−8.271***	2.936	−5.385**	2.181
UC	2.324	2.486	−1.194	2.017	7.636***	2.104	1.462	2.025	−5.505	4.088	−2.145	3.853	−11.307***	3.161	−6.576**	3.212
Wheaton	5.104**	2.103	−4.852***	0.925	5.170***	1.509	2.088	1.31	1.85	1.639	−0.846	2.208				
N	126		123		123		121		124		122		116		122	
Joint F	6.51		2134.3		9.56		15.3		121.53		52.11		56.83		33.5	

Standard errors are robust.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

the VWLS and DGMM regressions, respectively.[23] This suggests that foreign students may generate direct and indirect effects that would increase the degree completion of native students. In addition to improving the overall graduation efficiency of universities, international students generate positive externalities that increase the native graduation premiums.

We also observe that foreign students generate significant externalities that affect the master's graduation premiums of native students in California. Table 8 indicates that the presence of foreign master's students increases the university graduation premiums of the native students. One percentage point increase in the share of foreign graduates increases the university graduation premium by more than 0.6 native graduates. Lastly, we find that faculty to

[23] The Hansen overidentification test shows the validity of the lagged internal instruments in the DGMM regressions

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graduate student ratio increases the native master's graduation premiums.

4.2. Results from the one-step method

The correlations between the numbers of foreign and total degree recipients for PhD in Illinois and master's in California are 0.65 and 0.22, respectively. Because of these relatively lower correlations, we examine the effects of foreign degree recipients not only on the native but also on the total number of graduates at a university-discipline level. Thus, Table 9 reports the one-step regression results for PhD graduates, total and native, in Illinois, and Table 10 presents results for the total and native master's graduates in California. These results support the evidence provided in the two-stage regressions. Accounting for university and field fixed effects, we find that an increase in the number of foreign PhD recipients is positively associated with the numbers of total and native PhD recipients in Illinois. For one additional foreign PhD recipient, the total and native numbers of graduates increase by about 0.7 and 0.2, respectively. Besides, foreign master's recipients in California have similar effects on the total and native master's graduates.

The positive association between the foreign and the native number of graduates suggests that, after controlling for changes in the lagged native enrollments, the degree completion rates of native students are higher with a higher number of foreign graduates. This indicates the existence of positive graduation spillovers from foreign to native students enrolled in a given program which outweighs a possible adverse crowding out effects that may increase dropout rates and lower the completion rates of native students. Besides, controlling for lagged total enrollments, the positive association between the foreign and the total number of graduates suggests that an increase in the number of foreign graduates may lead to a higher overall degree completion rates of students in a given university. Finally, the coefficients of research expenditure, faculty salary, and public ownership have, for the most part, similar effects to those observed in the two-stage model.

5. Conclusion

This study analyzes the effects of international students on the graduate degree completion of all and native students using a two-stage method and a one-step method. In the two-stage method, we estimate graduation premiums measured as proportional differences in the number of master's and PhD recipients across universities, and examine how the share of foreign graduates influence the premiums. Degree completion rates differ across universities and fields of study. The premiums capture how many more or fewer students graduate in a given discipline of a university relative to the average in the sample. In the one-step method, we examine how foreign graduates affect the degree completion of native and all students after controlling for lagged enrollments, and university- and field-specific characteristics.

Results show that the share of foreign graduates increases university master's and PhD graduation premiums. The estimated coefficients, taking into account possibilities of endogeneity, suggest that one percentage point increase in the share of foreign master's and PhD graduates increases master's and PhD graduation premiums by about 1 and 0.7 additional graduates, respectively, among universities in Illinois. Similarly, a percentage point increase in the share of foreign graduates increases the master's graduation premiums by more than 0.5 graduates among universities in California. In addition, the results show that foreign degree recipients generate positive externalities that increase the native graduation premiums, suggesting that universities with a higher share of foreign graduates may achieve higher completion rates among the native graduate students. Results of the one-step regressions support the evidence provided in the two-stage method.

Appendix A

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